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A catalogue of tools and variables from crisis and routine care to support decision-making about allocation of intensive care beds and ventilator treatment during pandemics: Scoping review

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ABSTRACT

Purpose: This scoping review sought to identify objective factors to assist clinicians and policy-makers in making consistent, objective and ethically sound decisions about resource allocation when healthcare rationing is inevitable.
Materials and methods: Review of guidelines and tools used in ICUs, hospital wards and emergency departments on how to best allocate intensive care beds and ventilators either during routine care or developed during previous epidemics, and association with patient outcomes during and after hospitalisation.
Results: Eighty publications from 20 countries reporting accuracy or validity of prognostic tools/algorithms, or significant correlation between prognostic variables and clinical outcomes met our eligibility criteria: twelve pandemic guidelines/triage protocols/consensus statements, twenty-two pandemic algorithms, and 46 prognostic tools/variables from non-crisis situations. Prognostic indicators presented here can be combined to create locally-relevant triage algorithms for clinicians and policy makers deciding about allocation of ICU beds and ventilators during a pandemic. No consensus was found on the ethical issues to incorporate in the decision to admit or triage out of intensive care.
Conclusions: This review provides a unique reference intended as a discussion starter for clinicians and policy makers to consider formalising an objective a locally-relevant triage consensus document that enhances confidence in decision-making during healthcare rationing of critical care and ventilator resources.

1. Introduction

The COVID-19 pandemic has stretched hospital resources to their limits worldwide and in particular this has been reported in Italy, Spain, England, France, Brazil and the United States [1]. The world may experience ongoing epidemic waves, and while current resources may be sufficient to meet demand in non-crisis times, health systems in some countries could be overwhelmed, facing a shortage of ventilators for COVID-19 patients if the surge exceeds current resources. Of hospitalised patients, 4.6 to 45.9% have required treatment in the ICU [2-4]. Of all those requiring critical care, 75%, 76% and 88% ended up receiving treatment on a ventilator in the UK, the USA and Italy respectively [5-7]. The length of stay in ICU for COVID-19 patients on ventilators has been longer than in non-crisis periods (median 10 days IQR between 8 and 14 days in Italy) [7] and median 18 days IQR 9–28 in USA) [8]. Overall, people aged ≥75 years have experienced the highest COVID-19 mortality rates (71.3%–94.9% among the severe-critically ill in USA [9]; and RR 13.0, 95% CI 9.13–17.85 in UK [10]).

With rapidly increasing demand for ICU beds, resource capacity may be rapidly exceeded. In this situation, healthcare systems need to have evidence-based, equitable, and publicly defensible policies in place on how to ration potentially life-saving treatments [11,12]. Rules to guide

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allocation of life sustaining treatments will need to incorporate not only ethical considerations to prevent moral distress and public outrage and integration of patient values and treatment preferences. [13] Tools for decision-making in crisis time should also include objective clinical parameters to benefit the most, and those with the highest chances of survival, and to prevent biases at the time of triage.

Given the magnitude of this global emergency, there is vast heterogeneity in ventilator triage policies for COVID19, and policies are based (exclusively or in combination) on subjective perceptions of benefits to patients and medical need, ethical considerations, and some on objective clinical scoring systems [14].

We conducted a scoping review of publications that provide prognostic prediction tools or models, and/or objective triage recommendations which can inform allocation of ICU beds and/or ventilators. The specific objectives were:

1. To identify criteria for ICU admission and ventilator allocation used in epidemic situations as well as during routine care
2. To identify prognostic tools used in patient care during and outside epidemic situations that can potentially enhance confidence in decision-making about resource allocation during the COVID-19 pandemic; and
3. To discuss applicability of these tools for ICU triage in future global emergencies

2. Materials and methods

We searched the databases Medline and Embase on 1st May 2020 for English language articles published since 1st January 2002 (the year in which a SARS outbreak emerged) [15] and updated the search on the two databases screening on COVID19-specific triage/parameters on 28 June 2021. Additionally, we manually searched institutional websites of professional intensive care societies, reference lists of systematic reviews, pandemic guidelines from World Health Organization and Centre for Disease Control, and consulted with experts in the field (AP, CD, DH). The authors focused on articles where objective parameters or algorithms were presented with predictive accuracy or statistical validation of association with outcomes. Priority outcomes were need for escalation of treatment, need for ventilator treatment, and in-hospital or 30–90-day mortality. Details of the full search strategy are shown in Additional file 1, Supplement 1, and Table S1.1.

2.1. Inclusion criteria (PICO)

Target populations **(P)** were adults or children presenting to hospital during pandemic or non-crisis periods. We included studies with large sample sizes (>100 patients), that described clinical or laboratory parameters/algorithms to facilitate healthcare triage **(I).** Settings included were hospital wards, emergency departments, and ICUs. Eligible for inclusion were publications reporting either the accuracy of a prognostic tool (area under the receiver operating characteristics curve [AUROC], or sensitivity/specificity), the validity of a prognostic tool, or significant correlation between a prognostic tool and clinical outcomes (mortality or complication rates) using odds ratios and 95% confidence intervals (CI). We also included position statements and consensus documents or guidelines.

2.2. Exclusion criteria

We excluded pre-prints; recommendations based on i) subjective clinical judgments only; ii) unvalidated cut-off points or variables not statistically significantly associated with clinical outcomes; iii) disease-specific scores unrelated to COVID-19 (e.g. for blood cancers or chronic heart failure); recommendations related to injury in mass casualties; modelling studies; conference abstracts with insufficient data; non-Western health system studies; and reports with a focus on logistics, ethics, or surge capacity.

2.3. Comparators and outcomes

Comparators **(C)** for the validation studies were any other algorithm or laboratory test used by authors, or confirmation of outcomes at discharge or follow-up as specified. Our outcomes of interest **(O)** were performance of algorithms or individual clinical or laboratory factors in predicting patient outcomes, such as in-hospital, 30-day, 90-day, or 1-year mortality.

2.4. Data extraction and synthesis

Dyads of reviewers (MC, EK, RN, JS), independently screened titles, abstracts and full texts. All discrepancies were discussed until consensus was achieved. The following study information was extracted: author, year of publication, study country, publication type, characteristics of target population disease-specific information, whether pandemic or routine care, type of triage decision (for admission to ICU, discharge from ICU), decision algorithms, and characteristics of risk prediction tools. Algorithm components and variables were classified according to source from crisis or non-crisis situation, and whether they were used in intensive care, emergency departments or hospital wards. Summaries are presented by COVID-related or other crises, and by whether tools and parameters were used in pandemic or routine care. Domains for decision-making were discussed by the clinician authors based on their expertise until consensus reached. Ethical issues that could assist decision-making were also documented during the screening as they were considered contextually important. No meta-analysis was attempted, as this was a scoping review. Instead, a narrative synthesis is reported.

3. Results

Eighty publications (twenty COVID-19 specific) relating to 20 countries (eight studies covered multiple countries) met the eligibility criteria: Twelve pandemic guidelines/consensus papers/frameworks [2,12,16-25], Twenty-two pandemic triage factors/decision algorithms [8,26-44], and 46 algorithms, prognostic tools or guidelines for non-crisis care met our inclusion criteria: 19 for routine ICU care [45-63], 21 for routine emergency department care [64-84], and six for general ward care [63,85-89]. The screening process is illustrated in Supplement 1, Fig. 1, and reasons for exclusion of studies are presented in Supplement 1, Table S1.2.

As shown in Table 1, a majority of the consensus/guideline pandemic publications were from North America (8/12) and the target age groups were predominantly adults already admitted to ICU, with some also including triage consideration at the time of presentation to ED or on admission to ward. Most of the pandemic-related guidelines suggested criteria for ICU admission, and fewer addressed ICU step-down/discharge or ventilator allocation, although not all addressed all three questions. The pandemic algorithm-type publications tended not to report step-down or discharge criteria (Table 2).

3.1. Summary of COVID-specific consensus and guidelines

Examples of topics covered by the consensus/guideline publications give an indication of the variety and complexity of issues to consider, which could be reliant on a combination of patient status, the assigned decision-maker, local resources and patient's wishes. The Hong Kong ICU admission triage tool for COVID-19 presented concepts, definitions and examples of priority cases with added predictors such as frailty, comorbidity severity, organ failure scores, laboratory parameters and performance indicators for individual variables [22] The French prioritisation scheme proposed grading criteria to withhold and

Table 1
Characteristics of guidelines and consensus publications informing ICU Triage in pandemic situations $N = 12$.

Author and publication year	Country of study subjects or where guideline applied	Target population			Pathological process		Proposed benefit criteria		
		Age range (years)$^{\alpha}$	Admitted to ICU	ED/other hospital	Pneumonia/Lung	Multi-organ/sepsis	ICU Admission/not	Step-down/stop (ICU)	Ventilator access
COVID19-specific Guide/Consensus									
Maves US Task Force, 2020	USA	All ages	✓	✓	✓	✓	✓	✓	✓
Lecler et al., 2020	France	Al ages	✓		✓	✓	✓	✓	
Chuang et al., 2020	USA	Adults	✓			✓	✓	✓	✓
Joynt et al. 2021	HongKong	Adults	✓		✓	✓	✓	✓	✓
Swiss Academy 2021	Switzerland	All ages	✓	✓	✓	✓	✓	✓	✓
NICE 2021	UK	All ages	✓	✓	✓	✓	✓	✓	✓
Other crisis Guide Consensus									
Christian et al., 2006	Canada	0-paediatric	✓	✓	✓		✓	✓	
Devereaux et al., 2007	USA	All ages	✓				✓	✓	
Powell et al., 2008	USA	0 - older adult	✓	✓	✓	✓	✓	✓	✓
White et al., 2009	USA	12- older adult		✓	✓	✓			✓
Wilkens et al., 2010	USA	0- older adult		✓	✓	✓			✓
NewYork Taskforce, 2015	USA	0- older adult	✓		✓	✓	✓	✓	✓

withdraw critical care based on levels of resource scarcity (tension to saturation) [23] and likewise the Swiss guideline defines capacity stages A and B [25]. The Swiss COVID-19 triage guidelines for intensive care treatment covers triage pathway from the moment of hospital admission using frailty scores-age combinations, and comorbidity severity, followed by daily evaluation of treatment eligibility once an ICU resource is allocated [25]. The American College of Physicians guide emphasised decision-making transparency with families and the public, use of multidisciplinary committee, and re-assessment of critical care resource allocation [2]. The UK's COVID-19 rapid guideline consensus recommended use of a track-and-trigger system endorsed by NHS (NEWS2) to monitor deterioration and stop organ/respiratory support after communication with families when the anticipated outcome is not aligned with the goals of treatment [24].

The routine care algorithms included patients in emergency departments or ICU, and three were exclusively for babies and children [48,50,88]. Additional file 1, Table S1.2 shows the target populations, study types and context information for routine care.

3.2. Domains used for decision-making

A summary of references for recommendations to consider in the decision to escalate care, admit individuals to ICU, and allocate ventilators is presented in Table 3. One domain for decision making included variables and scores to determine patients' need for higher-level care (column A) to patients who may not yet be in ICU, ventilated or receiving other organ support but may do so later (Table 3, column A). Another domain for decision-making included predictors for patients who stand to benefit from ICU care or mechanical ventilation the most and should be prioritised (Table 3, column B). The Sequential Organ Failure Assessment (SOFA) score and its variants was the most widely used (or reported) for both ICU admission and discharge criteria, as well as to recommend ventilator allocation or removal.

Patients who stand to benefit the most from ICU admission typically suffer from a critically severe, treatable and potentially reversible deterioration of health. ICU treatment should also be consistent with the values and preferences of the patient [13,90]. When patients' are deteriorating despite ongoing ICU care, withdrawal of life-sustaining therapies, and transfer to ward and palliative care has to be considered. This process is known as 'reverse triage' [91] and variables to facilitate these decisions are listed in Table 3, column C. Withholding or withdrawing treatments must include discussions with the patient (if possible) and their family. Ideally during pandemic triage the possibility of future deterioration and need to discharge from ICU later should already be discussed on admission to ICU.

Multiple studies investigated predictors for mortality in the ensuing weeks and months after ED or ICU admission to inform decision-making, mostly in non-pandemic situations (Table 3, columns D and E). These prediction models can assist clinicians and patients in the decision-making about the appropriateness of ICU care by providing information about the expected recovery (or likely downward trajectory) following ICU admission and/or ventilator treatment [55,92,93].

3.3. Variables and prognostic factors used for decision-making in pandemic situations

Among the twenty-two pandemic-related publications, several expert consensus documents outlined factors that inform the allocation of ICU care and ventilator treatment (Table 4) and the usual criteria for requiring critical care interventions still applied.

The SOFA, qSOFA, and mSOFA score cut-offs were used to either determine priority for ICU or ventilator access or removal from a ventilator and/or discharge from ICU in futile situations. Likewise, the AGILITIES score and Simple Triage Scoring (STSS) for adults, the Paediatric Logistic Organ Dysfunction 2 (PELOD) triage score, the COVID-19 clinical risk score, and the Community Assessment Tools (CATs) criteria for adults and children were used to prioritise ICU admission or recommend ICU discharge due to a lack of benefit.

Age was a variable in six of the predictive approaches for pandemic situations [8,19,20,30,32,102]. Two studies outlined criteria for patients who do not require organ support or ICU because they are below the critical illness threshold [12,28].

As the pandemic progressed and the understanding of disease pathophysiology increased, a number of subsequent studies incorporated additional parameters into prognostic models. These were tested both prospectively and retrospectively in COVID-19 populations. Parameters included individual pre-morbid patient determinants (sex [39], frailty scores [37], body mass index [34]), additional diagnostic laboratory data (particularly those relating to inflammatory states such as C-reactive protein [34,39,44], D-dimer [8,44], procalcitonin [34,40], ferritin [34,44], interleukins [8,35,40] and lactate dehydrogenase [34,41,99]) and assessment of oxygen uptake ability (as determined by an arterial-to-inspired oxygen ratio) [36,37]. Two papers used radiological factors such as pulmonary artery diameter (assessed using chest CT) [43] and

Table 2
Characteristics of published algorithms and predictive factors informing ICU Triage in pandemic situations $N = 22$.

Author and publication year	Country	Sample size	Publication type			Target population			Pathological process		Proposed benefit criteria		
			Prospective	Retrospective		Age range (years)$^{\alpha}$	Admitted to ICU	ED/other hospital	Pneumonia/Lung	Multi-organ/sepsis	ICU admission/not	Step-down/stop (ICU)	Ventilator access
COVID-19 specific Algorithms/Factors													
Liang et al., 2020	China	1590		R		48.2 ± 15.2 (4–88)		✓	✓		✓		
Cummings et al., 2020	USA	1150	P			62 (51–72)	✓		✓	✓			
Schöning 2021	Switzerland	459	P			All ages	✓	✓	✓		✓		
Dorgham 2021	France	115	P			58 (IQR 49–66)	✓	✓		✓	✓		✓
Tang 2020	China	120	P			Adults	✓	✓	✓	✓	✓		
Xu 2021	China	2362		R		Mean 51.7 (>18)	✓		✓	✓	✓		✓
Wu 2020	China	299		R		50 (IQR 36–63)		✓	✓		✓		
Ryan et al., 2020	USA	53,001		R		Adults (>18)	✓		✓	✓			✓
Douville et al., 2021	USA	398		R		All ages	✓		✓	✓	✓		
Kesler et al., 2021	USA	504		R		Mean 61 (>18)	✓		✓	✓			✓
Chow 2020	USA	87		R		48 (IQR 21–88)		✓	✓	✓	✓		✓
Dres 2021	EU	1199	P			74 (IQR 72–78)	✓		✓	✓			✓
Stony-Brook 2020	USA	1325		R		62 (IQR 49–75)	✓		✓	✓	✓		
Esposito 2020	Italy	1469		R		Median 69 (>18)	✓	✓	✓	✓			✓
Other crisis Algorithms/Factors													
Guest et al., 2009	UK	255	P			60 (IQR 41–69)	✓		✓		✓		
Grissom et al., 2010	USA	1770	P	R		50 ± 20 53 ± 20	✓			✓		✓	✓
Khan et al., 2009	UK	8		R		26–52	✓			✓	✓	✓	
Adenjil et al., 2011	UK	62		R		18–71	✓		✓		✓		
Semple et al., 2013	UK	1520		R		0-older adult		✓	✓	✓			✓
Talmor et al., 2007	USA	5133		R		Mean 59 (≥ 18)		✓		✓	✓		✓
Killien et al., 2020	USA	3206		R		0-paediatric	✓			✓	✓		✓
Kim et al., 2012	USA	N/R			LR	0-paediatric	✓	✓	✓	✓	✓	✓	✓

*France, Switzerland, Belgium $^{\alpha}$ range or mean ± SD or median and IQR as reported in eligibility or findings sections of eligible articles (D): Derivation cohort; DK=Denmark; LR = Literature review; N/R = Not reported; SOFA = Sepsis-related Organ Failure Assessment P = Prospective; R = Retrospective

Table 3
Evidence-based variables and scores for decision-making about allocation of ICU care and ventilators based on predicted outcomes (during pandemics and routine care).

Factors and scores for decision-making	A) Predicts need for increased care resources/ICU care	B) High or intermediate priority for ICU and ventilator allocation based on potential benefit	C) Recommends Not for ICU or discharge from ICU or exclude from ventilator	D) Predicts in-hospital death	E) Predicts ICU discharge death or poor function 30, 90, 365 d
Other recommendations					
Guidelines, Consensus		[17,19,21-23,25,28,94,95]	[12,16-20,22,23,25,94,95]		
Triage scores, reviews	[26,34,36]	[3,21,28,32,33,36,45,96]	[11,27,33,55,63,96]	[8,32,38,43]	[37,38,89,93]
Scores/Indices					
SOFA/qSOFA/mSOFA	[26,65]	[3,12,16,18,19,28]	[12,16,18,26-29]	[18,27,29,67]	[45]
ICU scoring: APACHE II, PIM2, PELOD, ProVent14, SAPS II, SMART-COP, SI, STSS, SMS-ICU	[26,53,56,63,72,74,97]	[11,52,61,62]	[55,61,62]	[46,49-52,54,57-61,63,72,74,78,98]	[47,56,57,74]
Other routine scores: ALT, EWS, CURB65, CriSTAL, HOTEL, IDSA/ATS, mBTS, MPM, NIVO, REMS, SCAP, SCS, TIMM, WPS	[53,63,70,72,74,75,78]		[63]	[69,71,73,87,88,99]	[53,66,69,70,74,76,77,81,85,87]
Clinical & laboratory variables					
Sepsis	[65]			[65,67]	[86]
Shock Index	[26,72]			[26,32,71,72]	
Hypotension or requires vasopressors	[53,65,70]		[55]	[54,67]	[85]
Abnormal respiratory rate, respiratory failure, Low SpO_2, or pneumonia	[26,53,70]	[20]	[11,63]	[32,44,63]	[53,74,85]
Arterial Lactate				[80,100,101]	[64,79]
High creatinine or end-stage renal disease			[55,83]	[54,83]	[64]
Clinical conditions, demographics					
GCS/altered mental state	[32,53,65,70]			[32,54,63]	[54,76,85]
Cardiac arrest or resuscitation		[17,18]		[54,83]	
End-stage organ failure		[20]			
Advanced malignancy		[18]		[22,49,54]	[81]
Frailty/aged care residency/prior admission/obesity		[20]		[23,25,63,68,84]	[76,81]
Physical functioning, quality of life					[48,93]
Age (life cycle)	[32,70,97]	[18-20]	[55]	[22,25,44,52,55,72,81]	[76,81,85]

ALT = Admission Laboratory Tests; APACHEII = Acute Physiology and Chronic Health Evaluation; ATS = Australasian Triage Scale; CriSTAL = Criteria for Screening and Triaging to Appropriate aLternative care; CURB65 = Confusion, Urea, Respiration, Blood pressure age > 65; EWS = Early Warning Score; GS = Goodacre Score; H1N1 = Swine flu; HOTEL = Hypotension, Oxygen saturation, low Temperature, ECG changes and Loss of independence Score; IDSA/ATS 2007 = Infectious Diseases Society of America/American Thoracic Society 2007 Pneumonia Guidelines; mBTS = modified British Thoracic Society rule; MPM = Mortality Probability Models; NIVO=Non-Invasive Ventilation Outcomes; N/R = Not reported; PELOD-2 = Paediatric Logistic Organ Dysfunction 2; ProVent14 = Platelets, Requirement for vasopressor or dialysis after 14 days of ventilation; REMS = Rapid Emergency Medicine Score; SAPS = Simplified Acute Physiology Score; SAPSII = Simplified Acute Physiology Score; SCS = Simple Clinical Score; SI = Shock Index; SMART-COP=Systolic BP, Multilobar involvement, Albumin, Respiration, Tachycardia, O_2 saturation, pH; SOFA = Sepsis-related Organ Failure Assessment; SMS-ICU = Simplified Mortality Score for ICU; STSS = Simple Triage Scoring System; TIMM = Triage Information Mortality Model; TTS = Track and Trigger System; WPS = Worthing Physiological Scoring System.

radiomics (computer analysis of multiple radiology images) [42] to predict adverse patient outcomes including need for ventilation, ICU admission or death. Some dual combinations of laboratory and clinical parameters performed very well in predicting need for critical care [34,39]. However, combinations of all of radiological, laboratory and clinical data [42] may have superior prognostic value when compared to any other two categories taken together. Some described abilities to distinguish between 'mild' and 'critical' patients with very high levels of both sensitivity and specificity (several with an AUROC exceeding 0.9) [40]. Such systems may have greater utility in sorting patients earlier in their disease course (rather than scores that focussed on mortality once intubated or requiring ECMO [35]) and allocating resources accordingly.

Table S2.1 in Additional file 1, Supplement 2 lists specific details of some tools used for decision-making about ICU admission and ventilator allocation during pandemics along with their reported accuracy (AUROC, Odds Ratio or sensitivity/specificity). Some recommendations were ambiguous for patients who warranted high priority access to ICU care due to severity, but had a poor prognosis. The COVID-19 clinical risk score used 72 clinical, laboratory and medical history parameters present on admission to hospital of which 10 predicted either need for critical care, need for ventilator or the risk of in-hospital death for patients with COVID-19 [30]. An earlier and simpler 5-item triage tool also had composite outcomes for patients with a score of ≥3 [32]. The community assessment tool (CATs) was based on respiratory criteria, shock and altered level of consciousness to predict the need for mechanical ventilation or ICU admission, or the risk of death but did not indicate when to set a threshold for choosing a care pathway [31].

Table 4

Summary of consensus/taskforce/algorithm recommendations for rationing ICU care and ventilators during pandemics according to patient status and response to treatment.

Highest priority for ventilator and ICU access
• Patients with mild disease, Frailty score CFS ≤4, ASA score I-II and 1 organ failure [22]
• Initial SOFA≤11 who showed improvement (SOFA decreases) at 48 and 120-h, and those with initial SOFA <8 with little (<3 points decrease) or no improvement in the previous 72 h [21]; SOFA score ≤ 7 or single organ failure [28,33]
• Other more stringent criteria were SOFA <6, age 12–40 years, and absence of life limiting conditions [19].
• Hypoxaemia (SpO_2 < 90%) or impending respiratory failure [12,21] or SpO_2 < 92% with increased respiratory rate/exhaustion [31]
• Clinical evidence of shock (Systolic Blood Pressure < 90 mmHg) [12,21,23]
Intermediate priority for ICU or ventilator
• Mild frailty (CFS 5), ASA score II, mild disease and/or 2–3 organ failures [22]
• Patients with SOFA score 6–9, age 41–60 and minor comorbidities with small impact on long-term survival. [19]
• Patients with SOFA <8 with no improvement from initial assessment [21].
• Patient with SOFA 8–11 if no patient in the high priority category requires bed [28]
Exclusion/removal from ventilator treatment in the face of resource scarcity
• Patients who had experienced an unwitnessed cardiac arrest, have terminal cancer, or irreversible organ failure [18,23,25]
• SOFA >12 in patients with severe comorbidities [23,25] and high risk of death within 1 year including age ≥ 75 years. [19]
• AGILITIES score > 100 integrating current clinical parameters, medical and surgical history, treatments and tests administered in the previous 6 h, and using threats to healthcare providers as criterion to deny access [20]
• Patients near immediate death despite aggressive therapy, and those with unwitnessed cardiac arrest or cardiac arrest unresponsive to standard interventions [17,25]
Exclusion from/discharge from ICU (too ill to benefit from ICU support)
• SOFA score of >11 combined with comorbidities and not likely to benefit [12,18,27]
• A clear indication of ≥6 organ failures with a SOFA of 15, or severe chronic disease with short life expectancy (85+ years) [16]
• End-stage organ failure, on chronic life support, life expectancy <3–6 months, severe dementia or intracranial bleeding or severe trauma, or advanced metastatic disease, or patient/surrogate refuses admission [22,23]
• Unwitnessed cardiac arrest, metastatic cancer, end-stage organ failure [23,25,33]
• SOFA scores not improving after 48 h in mechanically ventilated patients [29]

3.4. Prognostic tools used in non-crisis situations

Our study also explored whether triage algorithms/factors used for ICU, emergency departments or in hospital wards in non-crisis situations (Additional file 1, Supplement 2, Table S2.2), could add value to the above pandemic recommendations. The majority of these prognostic indicators were derived from large patient population studies and predicted in-hospital or post-discharge mortality. Only four indicators were based on expert consensus, of which three used SOFA or qSOFA for predicting outcomes, [45,65,67], while the CURB65 score was used as ward-based rule to predict mortality [85]. The non-crisis tools applied predominantly to adult patients in routine ICU care (18 studies) or patients being assessed in emergency departments (21 studies), with only a few (5 studies) used in routine ward care.

Unlike pandemic tools, which focus on acute organ failure, many routine care decision-making algorithms rely more on patient history of chronic illness [50,54,57,62,68,76,77,81,82,84], admission type (emergency, medical, elective surgery, non-trauma) [46,47,51,54,55,57,81], and age [54,55,62,70,73,75,76,78,81,84,86,87].

3.5. Triage algorithms, scores and tools used in non-crisis ICU care

Instruments for decision-making about routine ICU triage also included SOFA, and qSOFA, but a diverse collection was a: Simplified Mortality Score for the ICU (SMS-ICU), ProVent 14 score, Simplified Acute Physiology Score (SAPSS II, SAPS III), SMART –COP score, Mortality Probability Models (MPM), and Acute Physiology and Chronic Evaluation (APACHE II, III) and for children the Revised Paediatric Index of Mortality and PELOD-2.

ICU-based algorithms relied predominantly on laboratory variables or acute treatments such as those for sepsis or respiratory failure [51,53,55,57-59,62] and two relied solely on a single biomarker cut-off: Secretoneurin [60] and Procalcitonin respectively [61]. Five of the 18 articles on routine care included algorithms to predict clinical deterioration with a need for ICU admission [52,53,56,62,65]. Only one article included a tool to predict the need for vasopressor treatment and respiratory support [53]. Two articles provided information on patients who are unlikely to benefit from (ongoing) ICU treatment [55,62].

3.6. Emergency department algorithms used in non-crisis situations

Emergency department decision-making algorithms combined laboratory tests and clinical history or examination: Severe community acquired pneumonia score (SCAP), Infectious Diseases Society of America/American Thoracic Society IDSA/ATS), the Shock Index (SI), Mortality in Emergency Department Sepsis (MEDS) score, Simple Clinical Score (SCS), Emergency Severity Index (ESI), Triage Information Mortality model (TIMM), and Criteria for screening and triaging to appropriate alternative care (CriSTAL). Two studies predicted in-patient mortality based only on frailty syndrome [68,84], and six studies based mortality predictions purely on laboratory test results [64,66,79,80,82,83].

Six of the 21 studies among patients in the emergency department predicted the need for potential transfer to ICU based on clinical and laboratory variables [70,72,74,77,78,82]. The other studies predicted mortality at different time points. One study focused on decision-making about ICU admission in patients on chronic dialysis [83]. Two studies provided recommended a score cut-off for referral to palliative care [77,81].

3.7. Ward-based triage used in non-crisis situations

Five scoring systems predicted in-hospital and 30-day mortality among ward-based patients (Simple Clinical Score, HOTEL, CURB65, NIVO, and Mortality Predictive Model for Children (MPMC) based on a combination of clinical criteria and laboratory test results [63,85-88]. One scoring system predicted the need for non-invasive ventilation in ward-based patients with COPD and was recommended for setting a ceiling of treatment [63].

3.8. Summary of variables and prognostic factors used for decision-making in non-pandemic situations

Table S2.2 in Additional file 1, Supplement 2 gives an overview of variables predicting poor patient outcome for decision-making about ICU admission (IDSA/ATS, ESI) or discharge in non-pandemic situations presented for ICU, ED and ward care. Several tools including SAPS II, APACHE II/III, SOFA) predicted in-hospital mortality risk. Results from the validation of Simple Clinical Score, CriSTAL tool, and Shock index, indicated a good predictive value to identify people who will require ICU admission, palliative care or will die in the short term post-discharge.

3.9. Using combined variables and prognostic factors for decision-making in pandemic situations

A simplified example of triage recommendations for pandemic times based on predicted prognosis is illustrated in Fig. 1. The parameters and accompanying cut-off points are extracted from the comprehensive factors used in both pandemic and routine care shown in Additional file 1, Supplement 2. Elements from this catalogue of triage criteria could be used to design locally relevant triage tools.

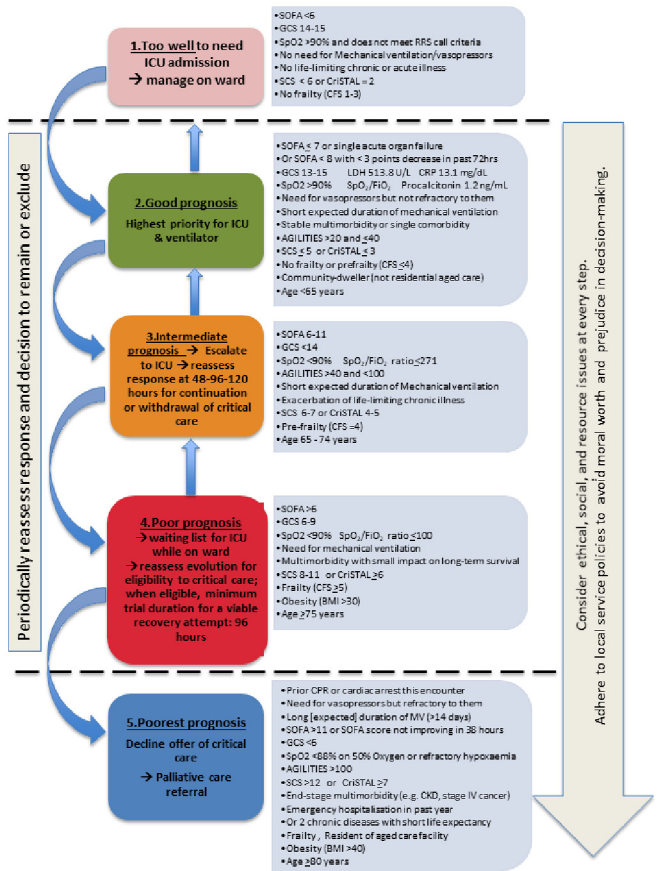

Fig. 1. Sample prioritisation criteria to determine access or exclusion from critical care services during pandemics using combinations of crisis and non-crisis algorithms about here.

In this priority setting scenario for pandemics, two types of patients are unambiguously outside eligibility thresholds and therefore excluded from access to critical care resources: patients in group 1 who are 'too healthy' and patients in group 5 who are 'too sick' (Fig. 1). For other severity profiles (patients in groups 2 to 5 with increasingly poorer prognosis) some parameters may be unknown at triage; a suite of alternatives are listed to assist with decision-making. Periodic reassessment at 48, 96 and 120 h is recommended [12,21,29,33,54] to determine the need to discharge to ward due to improvement, escalate treatment to ICU, or withdraw ICU treatment and refer for palliative care as indicated by the arrows between all groups.

The concept of a waiting list may not apply under normal circumstances, but in overwhelmed health systems, people with characteristics in group 4 may have to be managed on the ward until an ICU bed becomes available and no patient with a higher priority profile is competing for an ICU bed.

Patients who are deemed to be beyond salvageable –group 5 with the poorest prognosis–usually have already experienced a catastrophic event like a cardiac arrest and/or are unconscious and/or are refractory to vasopressors and/or need or have been on mechanical ventilation for 14+ days and/or have documented advanced chronic illness/frailty/age. The general recommendation is not to use scarce resources on these patients during a public health crisis. Importantly, no decision should be based on single parameters or undesirable individual characteristics.

3.10. Ethical and resource considerations in crisis decision-making

While not the focus of our review, we noted that social, ethical, and political considerations when making decisions about patients' access to ICU and ventilator treatment (Table 5) supported using patients' illness severity scores [12,19]. Others recommended against their use in isolation [95]. Guidelines warned against making judgments about the worth of individuals, while others associated age with a higher risk of death [20,26,30] or flagged a natural shorter life expectancy as an

Table 5
Ethical, legal, practical and clinical considerations when allocating ICU care ventilator treatment.

What to consider in ensuring fair rationing of resources
Ethical, legal and practical considerations
• Make triage policy and rationing criteria transparent to staff and the public to ensure understanding of the reasons for access restrictions [2,16,94,95]
• Establish local/regional partnerships to effectively manage resource shortages and triage pathways [2,16,91,95]
• When resources cannot be maintained, unequal treatment may be justified and choice determined on the basis of medical need and likely benefit [2,14,103] by using a proportionately lower amount of resources [96]
• People making decisions about resource allocation should not be the treating clinicians but preferably a central triage committee of senior clinicians and legal officers [2,16,94,103,105]
• First come first served or lottery/ random assignment if two patients with same level of risk present at the same time [96]
• Decision-makers should not be aware of patients' identity [20]
• Revise existing laws and develop liability protection for clinicians using scoring systems for decision-making about allocation of scarce resources [16,45]
• Priority to be given to those who have had less opportunity to live their lives [2,45,103]
• Align patients values and preferences with decisions to admit or remain in ICU [2,106,22,23]
• Build capacity for alternatives to ICU care before life-sustaining resources become limited and provide alternative options such as high quality palliative care [16,23]
• Ongoing adaptation of the triage process as new evidence of disaster experiences, research, planning, and modelling becomes available [16,107]
Clinical decisions
• Educate lay people to better understand goals of care so they can be partners in a shared decision-making process [90,108]
• Use best available objective parameters to determine patients' risk profile 16, and allocate patients to waiting lists or immediate resource access [16,22]
• Triage patients to higher level of care if they have the greatest medical need and higher chances of survival [21,96]
• Re-assess response to ventilator treatment and other therapies periodically, to see if patients are recovering or if they are deteriorating to confirm that the eligibility criteria are still met (i.e. risk of death, lack of improvement of SOFA after 48 hours) [20,29,96,103,2]
• If the patient does not deteriorate, commit the ventilator for 10-12 days 3. For patients on mechanical ventilation for 14+ days, clinicians should have a discussion with the family about the poor prognosis and goals of care [55]
• Refer to palliative care from ED if risk of death is very high (i.e. prior CPR or cardiac arrest) [17,18,45]
• Discharge patients from ICU who have an increased mortality risk or are unlikely to benefit from ICU treatment [16,18,27,29,103]
Apply objective criteria, set ceilings of treatment, discuss with families a referral to palliative care, and remove those from ventilator treatment who no longer meet objective criteria for benefit [2,11,19,20]
What to avoid when deciding on ICU/ventilator allocation
• Considering older age as single criterion for exclusion from higher level of care [18,45,52,81]
• Basing decisions on gender, race, gender, sexual orientation, religion, disability, social status, personal connections, wealth, citizenship, insurance status [20,95]
• Using obesity to inform prognosis in isolation from other risk factors [19]
• Prioritising healthcare workers [18],people with dependent parents or children [96]
• Allocating a ventilator to a pregnant woman to save a non-viable foetus (<24 weeks gestation) although appropriate to save the woman [20]
• Triaging people with a single condition to ICU ahead of those with comorbidities [18]
• Using the number of medical conditions rather than their severity to make decisions [54]
• Using Shock Index in isolation to rule out triage to ICU [72]
• Offering short trials of ICU to patients who are not eligible (low illness severity, minor comorbidities, young age) [19,95]
• Offering ICU beds to patients whose authentic values or informed treatment preferences are not consistent with ICU treatment/admission [13,90]

additional reason for excluding patients from critical care [16], and favoured young people as most years of life could potentially be saved [19,103]. Giving preferential treatment to those with dependent children [96], caregivers of elderly [96] or frontline pandemic health workers [18] were discouraged by some and promoted by others [95,104]. Likewise, discrepancies were found about the recommendation for decision-making leadership, some excluding treating clinicians [16,103,105] while others recommended the senior treating clinician should lead [95].

4. Discussion

This scoping review identified and systematically collated scores and algorithms from pandemic and non-crisis situations that can be used for ICU triage decision-making. Data was sourced from a range of best available objective tools to support the decision-making process and outlined their characteristics (62 publications on guidelines, frameworks, algorithms, laboratory parameters and predictive tools). Some of the identified tools were derived from influenza pandemics and non-respiratory disease public health emergencies, yet they can be extrapolated to other public health emergencies including COVID-19.

In addition, we summarised key ethical and social justice principles proposed by others for decision-making on allocation of intensive care beds and ventilator treatments during pandemics, including careful steering away from unintentional discrimination of vulnerable groups, consistent application of rules, transparency, and justification of service limitations.

4.1. How do the results fit in with previous research and policies?

It is generally accepted that triage protocols should only be activated when resource scarcity is imminent [26,62]; make best use of relevant objective criteria; consistently apply agreed rules; and be publicly transparent and ethically justifiable. ICU admission criteria vary from country to country [109] but generally admission is considered appropriate from the medical perspective, for those who are likely to benefit from mechanical ventilation, or support for single or multiple organ failure [109]. However, when resources are overwhelmed by a surge in number of cases requiring escalation of care, these criteria need to vary towards “crisis standards of care” [110].

We found that vital signs in critically ill patients commonly informed triage decisions during pandemics [32]. Quick and simplified scores (e.g. qSOFA) may offer simplicity at the expense of sensitivity and specificity. Using such scoring systems in isolation to deny access to care is controversial. [111] Conversely, complex algorithms with multiple variables increase the burden of data collection and may (SIRS and NEWS) or may not (APACHE) increase predictive ability. The appeal of some relatively simple tools with moderate to good predictive ability (mSOFA, qSOFA, SCS, CriSTAL, AGILITIES) is that they do not require additional testing, although some clinicians warn against the use of population-based algorithms in isolation to guide decisions for individuals [95]. Guidance on triage for older patients with frailty and comorbidities during routine care [112] remain valid as core decision-making considerations near the end of life.

4.2. No consensus on ethical and social considerations

We found mixed support for some of the subjective criteria in the expert consensus and triage publications. Fears of discrimination of elderly, functionally impaired, cognitively impaired, obese or immunosuppressed patients have been publicly expressed [19]. Under the “life cycle principle” younger patients receive priority because they have had the least opportunity to live through stages of life [19]. A different ethical principle to make allocation decisions is the “maximizing life-years” which takes into account a patient's life expectancy beyond age, incorporating comorbidities [45]. The principle behind giving healthcare workers priority [104] as recovering staff can contribute to saving lives did not receive much support in the consensus statements. The mixed views on non-clinical criteria could well reflect the complexity of different perspectives across policy-making committee members in health systems. Alternatively, it could be the result of our search targeting objective parameters and excluding articles exclusively addressing ethical aspects. This apparent contradiction on ethical dilemmas has been reported before, and acknowledged that disentangling them may not be possible as there is no gold standard for “right” or “wrong” and triage in under-resourced situations can only aim for “practical” [113].

4.3. Implementation strategies to manage clinician burden and public dissatisfaction

In overwhelmed health systems, many people with poorer prognosis may be diverted to palliative care earlier, thus increasing demand for accelerated staff training in the communication with patients and families about end-of-life care [114]. An external senior clinicians' decision-making committee to set ceilings of care could reduce the emotional burden on the treating clinicians [16,20,105]. A legal framework can protect healthcare workers from litigation if they allocate limited resources in accordance with ethical guidelines [16,115,116].

Triage protocols aim to maximise positive health outcomes for the largest possible number of patients but can have negative consequences for patients who are already hospitalised or treated in ICU for conditions not related to a pandemic who would not have been denied access under normal conditions [28]. Hence, we considered the use of objective prognostic factors and composite scores at assessment time as the most appropriate guiding tools in triage decision-making. As clinical evolution can rapidly change direction, those admitted to ICU should be reassessed at 48 and up to 120 h to determine ongoing eligibility for either continued use of ICU resources [26,29,113] or discharge to palliative care if deterioration becomes irreversible. The personalised approach to prognostic disclosure recommended in routine practice for terminal illness [117] may not be possible in mass emergencies and will have to be expedited at the time of admission. Patient and family involvement in treatment decisions may be limited by hospital policies concerned with service capacity and healthcare worker safety. However, when possible, recognising triggers for early palliative care referral and/or treatment withdrawal [118] and adhering to patient preferences [119] should be integral to management policies.

Recommendations to invite input from members of at-risk groups or their caregivers into algorithms to determine access to ICU and ventilators during pandemics as recommended by some [19,115,120] may not work in all cultures, and time pressure can make consultation with all stakeholders unlikely. Efficient allocation of ventilators may unintentionally further increase social inequalities [38,121] so transparency on the decision-making framework [19,107,120] is warranted to build public trust.

4.4. Strengths and limitations of this review

This scoping review provides a useful resource for decision-making about ICU and ventilator allocation during pandemics. As a discussion starter, it can inform objective guidelines beyond the guiding principles of preparedness, organisational management for resource allocation, expanded scope of practice, equity and social justice currently published [3,94,122-128]. Prognostic indicators and other decision tools presented here can be combined to create locally-relevant triage algorithms.

We did not include articles in non-English language due to lack of resources, or conduct risk of bias assessment of included studies as the purpose of this scoping review was to collate a wide range of risk prediction and decision tools, which will have to be adapted to local settings. We excluded some validation studies from low-income countries [129,130], which showed good predictive ability of the combined variables as there was the chance of lesser generalisability of their patient population or health system resources to those in industrialised nations –the focus of our study.

5. Conclusions

This catalogue of resources provides guidance on variables used to prioritise patients for critical care in the face of scarce life-sustaining resources. Patients' clinical or demographic characteristics alone and rigid triage systems are not the preferred way of allocating resources in a constrained healthcare system. Discrimination against certain population groups must be avoided at every level of disease severity. The patient perspective also needs to be taken into account if practicable. A combination of variables used in prognostic scores (based on chronic and acute risk factors) and other decision tools presented here can be combined to create locally-relevant triage algorithms to assist decisions about ICU admission and discharge and/or access to ventilator treatments during a pandemic. This unique resource will help service managers and clinicians with the emotional and ethical burden of having to select some patients over others for life-sustaining treatments. More importantly, objective guidelines will provide transparency about rationing resources to the patients and communities they serve.

Authors' contributions

Conceptualization: MC, CD, AP; Data curation: JC, MC, EK, RN, JS, CD; Formal analysis: MC, EK, RN, JS, CD, AP; Methodology: MC, CD, AP, DKH; Project administration: MC; Supervision: MC, CD; Writing - original draft: MC; Writing - review & editing: MC, CD, AP, EK, RN, JS, DKH, JC.

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Ethics approval

Not applicable.

Consent for publication

Not applicable.

Data sharing statement

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Declaration of Competing Interest

MC designed one of the tools included in this review but derives no financial benefit whatsoever from its open access use. All other authors declare that they have no competing interests.

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Appendix A. Supplementary data

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